PATENT ABSTRACTS OF JAPAN

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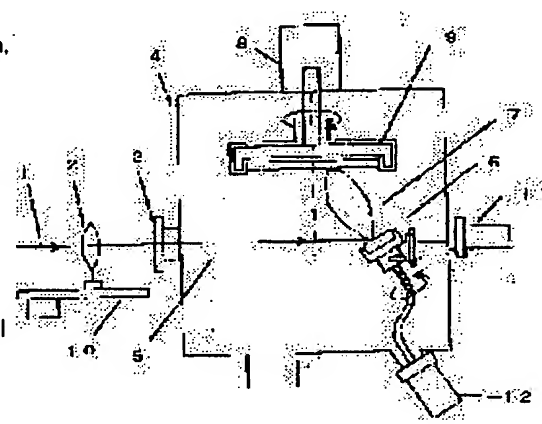
(54) FILM DEPOSITION METHOD BY LASER EVAPORATION

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a new film deposition method by laser evaporation for generating a thin film of high quality on a substrate wafer having a large area at a low cost and with high efficiency.
SOLUTION: In this film deposition method by laser evaporation, the laser beam 1 is converged by a collective lens 2, the laser beam 1 is incident from a laser beam introduction window 3 installed in a chamber 4, a laser plume 7 generated by the focusing on a target 6 having a rotating mechanism 12 and a horizontal moving mechanism 11 is brought into contact with the substrate 9 having a rotating mechanism 8 which is horizontally installed on the optical axis of the laser beam 1 to generate the thin film formed of a target substance on the substrate. A predetermined angle is formed between the normal direction of the target 6 and the direction of the optical axis of the laser beam 1, and the target 6 and the collective lens 2 are horizontally moved while maintaining them so that the distance between the target 6 and the collective lens 2 is equal to the focal distance of the laser beam 1 by the collective lens 2.



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CLAIMS

[Claim(s)]

[Claim 1] Condense a laser beam with a condenser lens and incidence of the laser beam is carried out from the laser installation aperture installed in the chamber. By making the substrate which has the rolling mechanism installed at a level with the optical axis of a laser beam in the laser plume generated by connecting a focus on the target which has a rolling mechanism and a horizontal migration device contact It is the laser vacuum evaporationo membrane formation approach which generates the thin film of the target matter on a substrate. Maintaining so that it may have an include angle with fixed direction of a normal of a target and direction of an optical axis of a laser beam and spacing of a target and a condenser lens may become equal to the focal distance of the laser beam by the condenser lens The laser vacuum evaporationo membrane formation approach characterized by carrying out horizontal migration of a target and the condenser lens.

[Claim 2] It is a degree type [several 1] about coordinate holding-time deltat [in / when the x-coordinate of a target is x=r in the system of coordinates which make a substrate core a zero and consider the direction of a x axis, and the direction of a substrate normal to be the directions of the y-axis for the substrate radial / the x-coordinate].

$$\Delta t = A x^n \qquad (1)$$

（ただし、

$n = 1.5 \sim 3$

$A = T / \{(\Delta r)^n + (2\Delta r)^n + (3\Delta r)^n + \cdots + r_A{}^n\}$

であり、

Δr：ターゲットの１回当たりの移動距離

r_A：ターゲットの全移動距離

T：全成膜時間　）

The laser vacuum evaporationo membrane formation approach according to claim 1 characterized by what it comes out and opts for.

[Claim 3] The condenser lens for being laser vacuum evaporationo membrane formation equipment which realizes the laser vacuum evaporationo membrane formation approach according to claim 1, and condensing a laser beam, The slider and the chamber for laser vacuum evaporationo for carrying out horizontal migration of the condenser lens, The target which has the laser installation aperture installed in this chamber, the direction of an optical axis of a laser beam where the direction of a normal was introduced in the chamber, and a fixed include angle, and has a rolling mechanism and a horizontal migration device, The substrate which has the rolling mechanism installed at a level with the direction of an optical axis of the laser beam introduced in the chamber is provided. The rotational speed, location, and horizontal migration rate of a target, Laser vacuum evaporationo membrane formation equipment with which the location of a condenser lens and a horizontal migration rate, and rotational speed of a substrate are characterized by the controllable thing at arbitration.

[Claim 4] Laser vacuum evaporationo membrane formation equipment which is laser vacuum evaporationo membrane formation equipment which realizes the laser vacuum evaporationo membrane formation approach according to claim 1, and is characterized by controlling the location of a condenser lens and a target, migration length, and passing speed, setting up the field of the arbitration on a substrate as a membrane formation field, and generating homogeneous membrane by motorised control using a computer.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Invention of this application relates to the laser vacuum evaporationo membrane formation approach. It is related with the laser vacuum evaporationo membrane formation approach which becomes possible [generating a quality thin film on the substrate wafer which has a big area in more detail].
[0002]
[Description of the Prior Art] Researches and developments are briskly done from the ability of laser vacuum deposition to generate a thin film comparatively easily from various kinds of matter, such as a metal, ceramics, and an organic substance, as a new thin film generation technique in recent years. In fact, the thin film generation technique by laser vacuum deposition is in the stage transitorium from the research phase in current and a laboratory to the practical use phase in the site of product manufacture, and the application to the industrial field with broad elevated-temperature superconducting thin film applicable field (microwave filter, antenna, delay element), semiconductor device field (thin film for flat panel display devices, optical film for IR tie ODO arrays), etc. is expected.
[0003] However, since the ** office of the membrane formation field was carried out near [small] the laser plume, it was not suitable for membrane formation processing of a up to [a substrate with a large area], and there was a limitation in application on industry.
[0004] For this reason, the proposal of many approaches has been made that generation of the quality thin film to a substrate wafer top with a large area should be realized with laser vacuum deposition. For example, the substrate (44) fixed to the target (42) and the substrate stage (43) to rotate which were fixed to the target stage (41) to rotate as shown in drawing 4 is arranged so that the medial axis of each rotation may set spacing of distance d, a laser plume (46) is formed of the laser beam (45) to which the travelling direction was fixed, and the off-axis method generation of a thin film is performed is mentioned. However, in this approach, although it is an approach by the simple device, the thin film generation in which the upper limit of one side of a substrate is about 25mm, and has an area large enough is impossible.
[0005] The inside of the laser plume (52) formed of the laser beam (51) to which the travelling direction was fixed by the approach which improved the off-axis method as shown in drawing 5 Although the approach (J. A.Geer et al, J.Vac.Sci.Technol.13(1995) pp.1176) a substrate (53) generates a thin film by repeating horizontal migration to rotation and coincidence is also proposed In this approach, since the device of equipment becomes very complicated with rotation and horizontal migration in order to realize heating of a substrate to coincidence further, it is said that utilization on a industrial scale is difficult.
[0006] On the other hand, as an approach of making the travelling direction of a laser beam fixing and scanning, as shown in drawing 6 , a laser installation aperture (61) is passed and a laser beam (62) carries out incidence to the interior of a chamber (63). By carrying out eccentric rotation of the condenser lens (64), by fluctuating the location of the focus which a laser beam (62) connects on a target (65), the formation range of a laser plume (66) is extended, and the approach (KH.Wu et al, Physica C289 (1993), p.230) of generating a thin film to the large area on a substrate (67) is proposed at this time. Moreover, as same approach, as shown in drawing 7 , the parallel displacement of a condenser lens (71) and the reflecting mirror (72) is carried out to coincidence. The location of the focus connected on the target (74) with which the laser beam (73) is having the location fixed is fluctuated. In connection with this, the approach (KFujino et al, Appl.Supercond. Vol.5 (1997), p.41) of generating a thin film on the substrate (76) which rotates by extending the formation range of a laser plume (75) is also proposed. Although membrane formation of a large area becomes possible, in order to prepare a target with a big area upwards and to make the focal location of a laser beam scan greatly on a target by these approaches, a big laser installation aperture becomes indispensable. Usually, the ingredient used as a laser aperture is an expensive quartz or sapphire, it is necessary to exchange periodically for damage by adhesion contamination and laser radiation of the vacuum evaporationo matter, and, moreover, an improvement in consideration of cost performance is desired.
[0007] Invention of this application is made in view of the situation as above, and makes it the technical problem to offer low cost and the new laser vacuum evaporationo membrane formation approach realized by being efficient for generation of the quality thin film on a substrate wafer with a big area.
[0008]
[Means for Solving the Problem] Invention of this application condenses a laser beam with a condenser lens, and incidence of the laser beam is carried out from the laser installation aperture installed in the chamber. By

making the substrate which has the rolling mechanism installed at a level with the optical axis of a laser beam in the laser plume generated by connecting a focus on the target which has a rolling mechanism and a horizontal migration device contact It is the laser vacuum evaporationo membrane formation approach which generates the thin film of the target matter on a substrate. Maintaining so that it may have an include angle with fixed direction of a normal of a target and direction of an optical axis of a laser beam and spacing of a target and a condenser lens may become equal to the focal distance of the laser beam by the condenser lens The laser vacuum evaporationo membrane formation approach characterized by carrying out horizontal migration of a target and the condenser lens is offered (claim 1).

[0009] The laser vacuum evaporationo membrane formation approach of invention this application is a degree type [0010] about coordinate holding-time deltat [in / when the x-coordinate of a target is x=r in the system of coordinates which make a substrate core a zero and consider the direction of a x axis, and the direction of a substrate normal to be the directions of the y-axis for the substrate radial / that x-coordinate].

[Equation 2]

$\Delta t = A x^n$

（ただし、

$n = 1.5 \sim 3$

$A = T / \{ (\Delta r)^n + (2\Delta r)^n + (3\Delta r)^n + \cdots + r_A{}^n \}$

であり、

Δr：ターゲットの１回当たりの移動距離

r_A：ターゲットの全移動距離

T：全成膜時間　）

[0011] It is characterized by what it comes out and opts for (claim 2). Moreover, the condenser lens for being laser vacuum evaporationo membrane formation equipment which realizes the above-mentioned laser vacuum evaporationo membrane formation approach, and condensing a laser beam, The slider and the chamber for laser vacuum evaporationo for carrying out horizontal migration of the condenser lens, The target which has the laser installation aperture installed in this chamber, the direction of an optical axis of a laser beam where the direction of a normal was introduced in the chamber, and a fixed include angle, and has a rolling mechanism and a horizontal migration device, The substrate which has the rolling mechanism installed at a level with the direction of an optical axis of the laser beam introduced in the chamber is provided. The rotational speed, location, and horizontal migration rate of a target, A condenser lens, a location and a horizontal migration rate, and the rotational speed of a substrate provide arbitration with the laser vacuum evaporationo membrane formation equipment characterized by the controllable thing (claim 3).

[0012] Furthermore, it is laser vacuum evaporationo membrane formation equipment which realizes the above-mentioned laser vacuum evaporationo membrane formation approach, and the location of a condenser lens and a target, migration length, and passing speed are controlled by motorised control using a computer, the field of the arbitration on a substrate is set up as a membrane formation field by it, and the laser vacuum evaporationo membrane formation equipment characterized by generating homogeneous membrane is also offered (claim 4).

[0013]

[Embodiment of the Invention] Although invention of this application has the description as above-mentioned, it explains the gestalt of that operation below.

[0014] the laser vacuum evaporationo membrane formation approach of invention this application — if it is, the laser beam irradiated from the laser light source is first condensed with a condenser lens, and incidence of the laser beam is carried out to the interior of the chamber for laser vacuum evaporationo from the laser installation aperture installed in the chamber for laser vacuum evaporationo. The focus of the laser beam by which incidence was carried out to the interior of the chamber for laser vacuum evaporationo is connected on the target fixed to the target stage to rotate, and the laser plume by the target generates it by excitation of a laser beam. When the tip of the generated laser plume contacts a substrate, the target matter accumulates on a substrate. On a substrate, the thin film by the matter of a target is generated by rotating a substrate, moving a target to the direction of a laser optical axis, and a horizontal.

[0015] the laser vacuum evaporationo membrane formation approach of invention this application — if it is, in case a target carries out horizontal migration in the direction of a laser optical axis, it also moves a condenser lens to a substrate and a horizontal synchronizing with a target. Spacing of a target and a condenser lens is set up so that it may become equal to the focal distance of the laser beam by the condenser lens. Thereby, excitation of a target is performed under the always same conditions from the focus of a laser beam always being connected on a target, and it becomes generable [a thin film with uniform thickness].

[0016] moreover, the laser vacuum evaporationo membrane formation approach of invention this application — if it is, it is also possible by controlling the horizontal migration distance of a target and a condenser lens to generate the thin film of the magnitude of arbitration on a substrate.

[0017] furthermore, the laser vacuum evaporationo membrane formation approach of invention this application — if it is, since a substrate does not need to move only in rotation, it is fixed, and is equipped with a heating heater and only the substrate electrode holder built into the heating heater by approaching rotates it.

Therefore, it becomes possible to perform easily heating at high temperature of a large-sized substrate.
[0018] In the laser vacuum evaporationo membrane formation approach of invention this application, it has realized crossing throughout the substrate of a large area and obtaining homogeneous thickness in a high precision also by setting up the time amount by which a target is held in that location according to a location. Below, this approach is shown concretely.
[0019] A substrate (81) core as shown in drawing 8 is made into a zero, in the system of coordinates which consider the direction of a x axis, and the direction of a substrate normal to be the directions of the y-axis for the substrate radial, a laser beam (83) is irradiated by whenever [with the direction of a normal of a target (82) / include-angle / to make / alpha], excitation evaporation of the target matter is carried out, and the case where membranes are formed on a substrate is considered. Although the thin film generally deposited on a substrate takes distribution of the thickness according to a cosine rule at this time, in order that a laser plume (84) may spread slightly in the direction of incidence of a laser beam and may generate in it, the thickness of a thin film (85) will become uneven in fact. Moreover, at the outermost edge of a substrate, it becomes the cause by which it also becomes uneven [thickness] that only the abbreviation one half of a laser plume contributes to vacuum evaporationo.
[0020] Although it is possible to obtain the thickness of homogeneity by setting up so that it may be proportional about r and delta t theoretically if time amount (coordinate holding time) which holds a target in the location is set to deltat when a target is in the coordinate of x=r (mm), in fact, there is a problem as aforementioned and thickness serves as an ununiformity.
[0021] Then, the thin film which crosses throughout a substrate and has uniform thickness is generated by defining the relational expression of r and delta t as follows.
[0022]
[Equation 3]

$$\Delta t = A x^n \qquad (1)$$

（ただし、
$n = 1.5 \sim 3$
$A = T / \{ (\Delta r)^n + (2\Delta r)^n + (3\Delta r)^n + \cdots + r_A{}^n) \}$
であり、
Δr：ターゲットの１回当たりの移動距離
r_A：ターゲットの全移動距離
T：全成膜時間　）

[0023] Moreover, all membrane formation time amount is found by the degree type.
[0024]
[Equation 4]

$$T = \frac{\pi}{4} \frac{D^2 \mu \rho}{fm} \qquad (2)$$

（ただし、
m：レーザー１パルス当たりのターゲット物質の蒸発量（g／パルス）
μ：生成される薄膜の膜厚（cm）
D：基板の直径（cm）
ρ：薄膜物質の密度（g/cm^3）
f：レーザービームの照射繰り返し数（パルス／s）　）

[0025] The relational expression of a formula (1) is found out experimentally and realized in precision with high generating the thin film which has the thickness of homogeneity on the substrate of a large area by setting up coordinate holding-time deltat at the time of target coordinate x=r according to a formula (1).
[0026] As laser vacuum evaporationo membrane formation equipment which realizes the laser vacuum evaporationo membrane formation approach of invention this application, as illustrated as drawing 1 , a laser beam (1) passes a condenser lens (2), and is introduced into the interior of a chamber (4) from a laser installation aperture (3). The laser beam (1) introduced into the interior of a chamber (4) excites an epilogue and a target (6) for a focus on the target (6) currently installed by inclining so that the direction of a normal may have a fixed include angle to the direction of a laser optical axis (5), and it forms a laser plume (7). The point of a laser plume (7) contacts the substrate (9) which has the rolling mechanism (8) horizontally installed to the incidence laser optical axis (5), and generates a thin film on a substrate (9).
[0027] A condenser lens (2) is installed on a slider (10), and horizontal migration is possible for it in the direction of a laser optical axis (5). Moreover, the support device is connected with the horizontal migration device (11) and the rolling mechanism (12), and horizontal migration and rotation are possible for a target (6). A target (6) and a condenser lens (2) are maintained so that both spacing may become equal to the focal distance of the laser beam by the condenser lens (2), and they carry out both-way migration in the direction level in the direction of a laser optical axis.

[0028] In the laser vacuum evaporationo membrane formation equipment of invention of this application, control of the location of a condenser lens and a target, migration length, and passing speed may be made by motorised [using computer control].
[0029] Although invention of this application has the above description, it shows an example below and explains it to it still more concretely.
[0030]
[Example] an example 1 — an example explains concretely derivation of the constants n and A which constitute the relational expression of the formula (1) in the laser vacuum evaporationo membrane formation approach of invention this application.
[0031] When a YBa2Cu3Oy (YBCO) superconductor is used as target matter, the evaporation m of the target matter per laser 1 pulse under the conditions of 2 serves as 0.3microg / pulse laser power consistency 4 J/cm2 and 3mm of laser radiation aspect products.
[0032] Moreover, the consistencies rho of YBCO are 3.5 g/cm3, and when 1.2cm and thickness mu of a thin film generated are set [the several f exposure repeat of a laser beam] to 0.4 micrometers for the diameter D of ten pulses /s, and a substrate, all the membrane formation time amount T can be found with 5300 seconds from a formula (2).
[0033] About a target, conditions for thickness to become uniform from an experiment, when moving migration length deltar per time as 5mm toward a core from the outermost marginal coordinate (x= 60 (mm)) of a substrate become settled with n= 1.5, and time amount deltatk (k= 1, 2, —, 12) by which a target is held at the coordinate xk of a migration place is given by the degree type for every migration.
[0034]
[Equation 5]

$$\Delta t_k = A x_k^{\,n} \qquad (3)$$

[0035] Therefore, [0036]
[Equation 6]

$$T = \sum_{k=1}^{12} \Delta t_k = \sum_{k=1}^{12} A x_k^{\,1.5} = A\left(5^{1.5} + 10^{1.5} + 15^{1.5} + \cdots + 60^{1.5}\right) \qquad (4)$$

[0037] It ******(ed), the above-mentioned constant was substituted, A= 2.1 could be found, and the relational expression of the coordinate holding time of a target and a coordinate was drawn.
Under the conditions of example 2 example 1, the thin film by the laser vacuum evaporationo membrane formation approach of invention this application was generated. The laser vacuum evaporationo membrane formation equipment which has the configuration illustrated by drawing 1 as laser vacuum evaporationo membrane formation equipment was manufactured.
[0038] In the produced laser vacuum evaporationo membrane formation equipment, the focal distance of a condenser lens was 700mm. Using the YBa2Cu3Oy (YBCO) superconductor with a diameter of 35mm, the direction of a normal made the target incline 50 degrees to an incidence laser optical axis, and installed in it. As a horizontal migration device of a target, the stroke 120mm horizontal migration installation machine was used. As laser installation aperture material, the disk with a diameter of 35mm made from a quartz was used. The substrate used the glass disk with a diameter of 120mm.
[0039] a target — migration length delta — every r= 5mm, it set up so that between holding-time deltat=Axn might be stopped. More here than an example 1, it was referred to as A= 2.1 and n= 1.5. Setting spacing of a target and a condenser lens as 700mm which is the focal distance of a lens, both total displacement distance was 60mm.
[0040] Moreover, generation of a thin film was performed at the room temperature under the oxygen of ambient atmosphere 1.5x10-1Torr. The number of laser radiation repeats was made into 10 pulses per second. The result of having measured substrate radial thickness distribution of the generated thin film by the diamond sensing-pin type thickness gage is shown in drawing 2 . The error of thickness was **10% or less in the diameter of 100mm.
[0041] Moreover, at this time, rotation of a target was aimed at the excavation phenomenon by immobilization of the exposure location of a laser beam not occurring, it came out enough with the rotational speed of about 1 rpm extent, and a certain thing was checked.
With the laser vacuum evaporationo equipment produced example 3, nickel radical alloy plate (50mmx50mm) which prepared the yttria-stabilized-zirconia buffer layer in the substrate was heated at 750 degrees C, and membranes were formed under the oxygen of ambient atmosphere 1.5x10-1Torr. About the target and the condenser lens, migration length deltar was set as 2mm in holding-time deltat=Axn A= 0.016 and n= 3 using the stepping motor by computer control. The total displacement distance of a target and a condenser lens was 30mm. Moreover, the number of laser radiation repeats was made into 7 pulses per second.
[0042] The thickness of a thin film and superconduction transition-temperature distribution which were generated are shown in drawing 3 . Drawing 3 shows that both thickness and superconduction transition temperature show good homogeneity.
[0043]
[Effect of the Invention] It becomes possible to generate the thin film which has a large area on the substrate

of the magnitude of arbitration by the laser vacuum evaporationo membrane formation approach which is invention of this application. moreover, the laser vacuum evaporationo membrane formation approach of invention this application — since a laser installation aperture can be miniaturized, the costs accompanying exchange of an expensive quartz or the installation aperture made from sapphire are reduced sharply. furthermore, the laser vacuum evaporationo membrane formation approach of invention this application also has the effectiveness which the use effectiveness of the source material of an expensive target boils markedly, and heightens from a target not being dependent on the magnitude of a substrate theoretically.

[0044] Thus, by the laser vacuum evaporationo membrane formation approach of invention this application, it is efficient, and low cost and since it realizes, that utilization is expected for generation of a quality thin film.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the schematic diagram showing the gestalt of operation of the large area laser vacuum evaporationo membrane formation equipment which is invention of this application.
[Drawing 2] In the example of invention of this application, it is drawing having shown thickness distribution of the thin film generated on the glass substrate of the diameter of 100mm.
[Drawing 3] In the example of invention of this application, it is drawing having shown the thickness distribution of a thin film and superconduction transition-temperature distribution which were generated on nickel radical alloy substrate with a buffer layer of the diameter of 50mm.
[Drawing 4] It is the schematic diagram having shown the laser vacuum evaporationo forming-membranes method by the conventional technique.
[Drawing 5] It is the schematic diagram having shown the laser vacuum evaporationo forming-membranes method by the conventional technique.
[Drawing 6] It is the schematic diagram having shown the laser vacuum evaporationo forming-membranes method by the conventional technique.
[Drawing 7] It is the schematic diagram having shown the laser vacuum evaporationo forming-membranes method by the conventional technique.
[Drawing 8] It is the schematic diagram showing the situation of thin film generation in the large area laser vacuum evaporationo membrane formation approach which is invention of this application.
[Description of Notations]
1 Laser Beam
2 Condenser Lens
3 Laser Installation Aperture
4 Chamber
5 Laser Optical Axis
6 Target
7 Laser Plume
8 Rolling Mechanism
9 Substrate
10 Slider
11 Horizontal Migration Device
12 Rolling Mechanism
41 Target Stage
42 Target
43 Substrate Stage
44 Substrate
45 Laser Beam
46 Laser Plume
51 Laser Beam
52 Laser Plume
53 Substrate
61 Laser Installation Aperture
62 Laser Beam
63 Chamber
64 Condenser Lens
65 Target
66 Laser Plume
67 Substrate
71 Condenser Lens
72 Reflecting Mirror
73 Laser Beam
74 Target
75 Laser Plume
76 Substrate

81 Substrate
82 Target
83 Laser Beam
84 Laser Plume
85 Thin Film

[Translation done.]